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"Seven minutes of terror"

How do you slow a spacecraft down from 13,000mph to zero in just over 400 seconds?

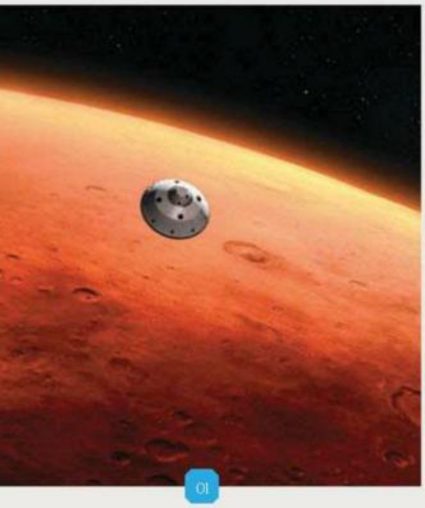
Set to land on 6 August 2012, MSL's groundbreaking Sky Crane will enable the craft to traverse Mars's atmosphere before its make-or-break touchdown on the planet's surface in a descent which NASA has described as "seven minutes of terror".

A landing mechanism that is as thrilling as it is terrifying, the Sky Crane could revolutionise how we land on other worlds. Previously, it was thought that air bags would be the only option to land on a planet such as Mars, but now it's widely believed that future off-Earth landings will use a Sky Crane design to lower vehicles to the surface.

Curiosity will have a much greater degree of control as it plummets through the Martian atmosphere than any mission before it. As it descends it will jettison some weights, putting the centre of mass of the descent capsule off balance and allowing the craft to manoeuvre through the atmosphere.

Such is the accuracy of the descent that NASA has been able to pinpoint a fairly precise area in which it expects Curiosity to land. The landing culminates with a rocket-powered descent after the parachute phase.

One of the benefits of this landing design is that Curiosity is placed straight down onto the surface rather than rolling off a ramped platform like Sojourner, Spirit and Opportunity. While alleviating some hazards, such as the ramp getting stuck, Curiosity might still encounter problems. If it lands on top of a rock engineers will need to carefully manoeuvre it to a safer position. Mission controllers must make sure there are no hazards immediately around the vehicle, such as rocks or an uneven surface, before it can begin scientific operations. ■



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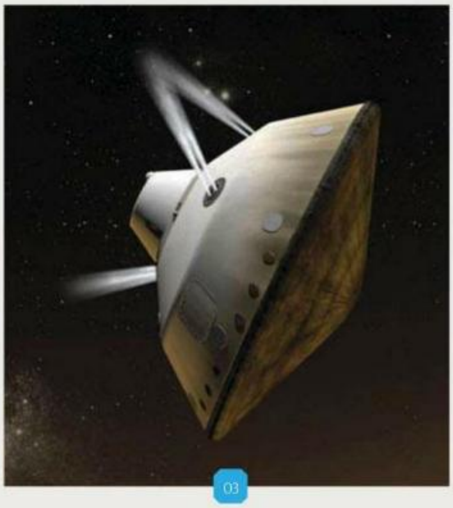

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1st minute: Dead or alive

Curiosity encounters the Martian atmosphere travelling at 21,000kph (13,000mph), more than 17 times faster than the speed of sound on Earth. The whole landing lasts seven minutes but it takes 14 minutes for Curiosity to communicate with Earth, so when ground control receives word that the rover has hit the atmosphere, it will have been alive or dead on the surface for seven minutes.

2nd minute: Into the frying pan

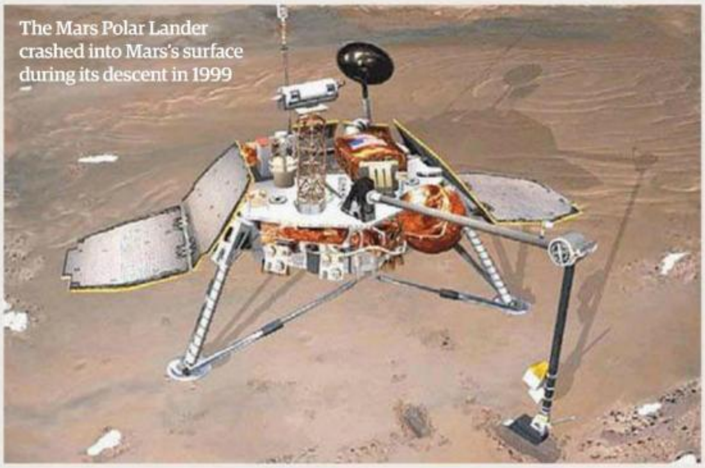
The atmosphere of Mars is 100 times thinner than Earth's. However, while it is not too thin to slow a spacecraft down completely, it is thick enough to tear an unprotected spacecraft apart. Therefore, as the capsule slams into the atmosphere, its heat shield bears the brunt of a 1,600°C (2,900°F) heat from atmospheric drag, glowing like the surface of the Sun.

3rd minute: Steering through the fire

As MSL makes its way through the atmosphere it is constantly steering itself with reaction thrusters, guiding itself like an aeroplane so that it can land in a precise area. In fact, it can manoeuvre so much that it could even perform an 'S' turn in the air.

4th minute: Chute for glory

After exiting the atmosphere the capsule will still be travelling at 1,600kph (1,000mph). To continue the deceleration, the largest and strongest supersonic parachute that has ever been built is deployed, snapping open at an incredible 5gs. Weighing just 100 pounds, it must withstand a force of 29,500kg (65,000 pounds) as it slows down the rover.

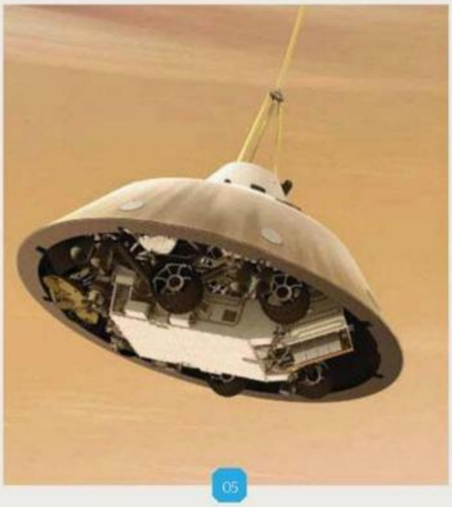


The Mars Polar Lander crashed into Mars's surface during its descent in 1999

What could go wrong?

At the time of going to print, Curiosity is still on its way to Mars. Therefore, by the time you're reading this, you might know already if it has made it safely to the surface or not. If it has, great! But if it hasn't, what might have gone wrong? As this is such a precise mission there is so much that could fail. During the intricately choreographed process every single aspect must work perfectly for the rover's seven-minute landing procedure to be a success. For example, if the parachute deploys too early it will be ripped to shreds. If the Sky Crane fails to disconnect it will pull the rover back into the sky before coming back to collide with Mars. Or, the mission could work flawlessly, but MSL could accidentally land on a large rock or loose sand, leaving it stuck on the surface.

However, NASA is optimistic. Not only has every eventuality been hopefully accounted for, but it has successfully completed a rocket landing before. Its Phoenix lander, in 2008, used rocket propulsion to lower itself to the surface of Mars's North Pole, although it didn't employ the same Sky Crane winch concept as Curiosity. There's no doubt, though, that if the rover lands it will be one of the greatest space exploration accomplishments of all time.



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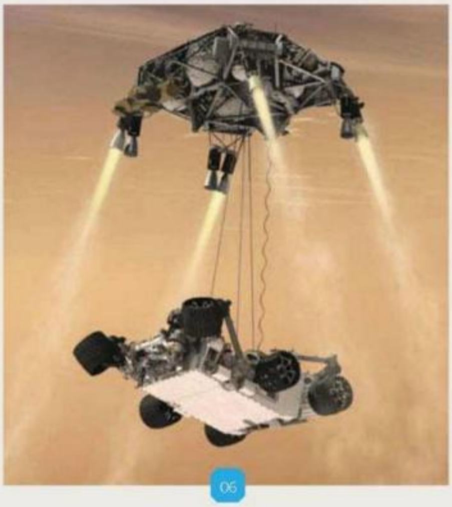

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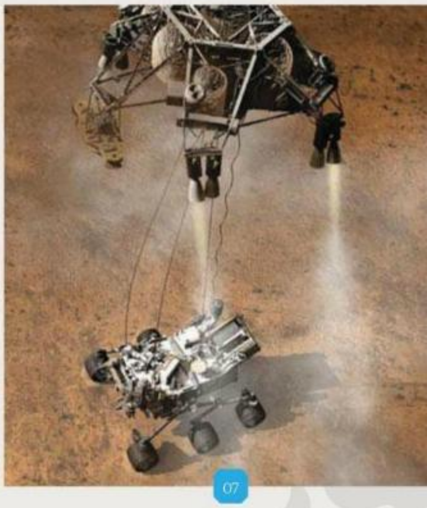

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5th minute: Cut off point
The parachute slows the craft down to 320kph (200mph), but this is not slow enough to land. The lower heat shield is no longer needed, so this is jettisoned, and then the upper portion of the parachute flies off, leaving the rover and its Sky Crane in freefall.

6th minute: Sky Crane
Eight rockets on the Sky Crane suddenly spring into action, taking the rover off to the side to avoid the parachute overhead. This mechanism must then kill the horizontal and vertical velocity of the spacecraft and head for the planned landing site at the bottom of Gale Crater, right beside the 5.5km (3.4-mile) high Mount Sharp.

7th minute: Touchdown
The last minute of the mission is the riskiest. At this point the Sky Crane lowers the rover down from a height of 20 metres (65 feet) on four cables that are each 6.4 metres (21 feet) long. Slowly, the rover is touched down on the surface, the cables are released from the rover and the Sky Crane flies off to crash in the distance so that it does not land on the rover. Seven minutes later, ground control will receive a signal from the rover confirming it has made it to the surface, and the crux of the mission can begin.

Landing Zone at Gale Crater

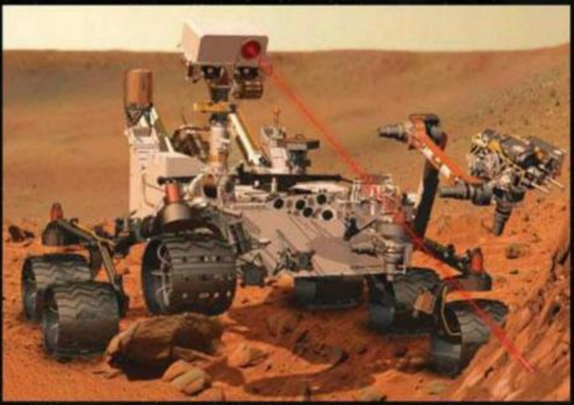
A year on Mars

What will Curiosity do once it has landed?

After landing, Curiosity enters the first drive phase, when engineers will conduct tests on the rover for five days to ensure it is in a "safe state" before moving it for the first time.

During the first five days several instruments will be deployed and tested, including the High Gain Antenna for communications with Earth and the sampling system. Once this has been completed, the rover will then run through some further checks before it is ready to move into uncharted Martian terrain for the first time.

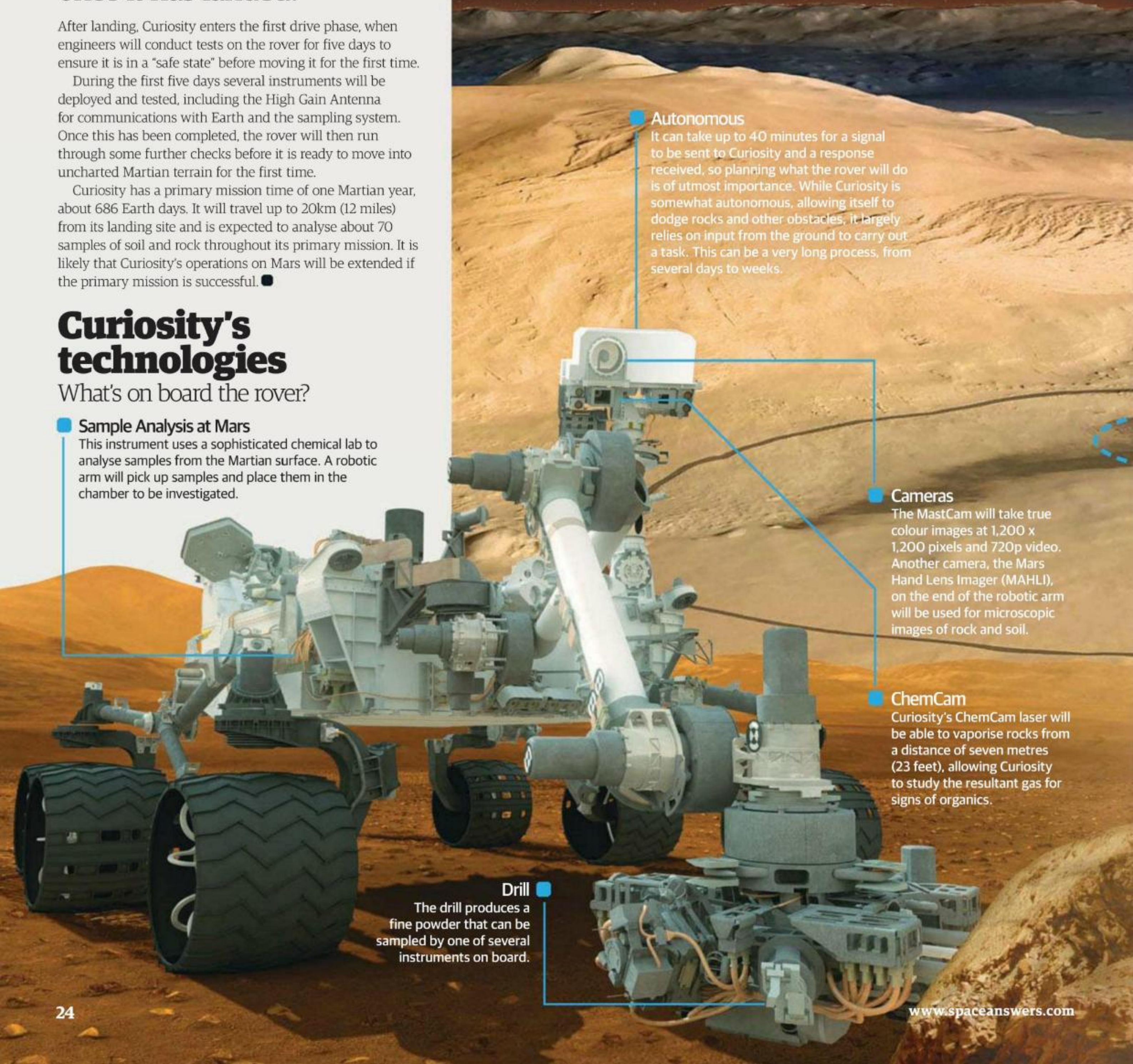
Curiosity has a primary mission time of one Martian year, about 686 Earth days. It will travel up to 20km (12 miles) from its landing site and is expected to analyse about 70 samples of soil and rock throughout its primary mission. It is likely that Curiosity's operations on Mars will be extended if the primary mission is successful. ■



The ChemCam laser will allow Curiosity to examine the composition of rocks and soil on Mars

Curiosity's technologies

What's on board the rover?



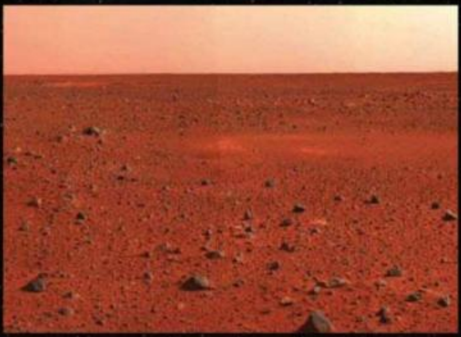
Sample Analysis at Mars
This instrument uses a sophisticated chemical lab to analyse samples from the Martian surface. A robotic arm will pick up samples and place them in the chamber to be investigated.

Autonomous
It can take up to 40 minutes for a signal to be sent to Curiosity and a response received, so planning what the rover will do is of utmost importance. While Curiosity is somewhat autonomous, allowing itself to dodge rocks and other obstacles, it largely relies on input from the ground to carry out a task. This can be a very long process, from several days to weeks.

Cameras
The MastCam will take true colour images at 1,200 x 1,200 pixels and 720p video. Another camera, the Mars Hand Lens Imager (MAHLI), on the end of the robotic arm will be used for microscopic images of rock and soil.

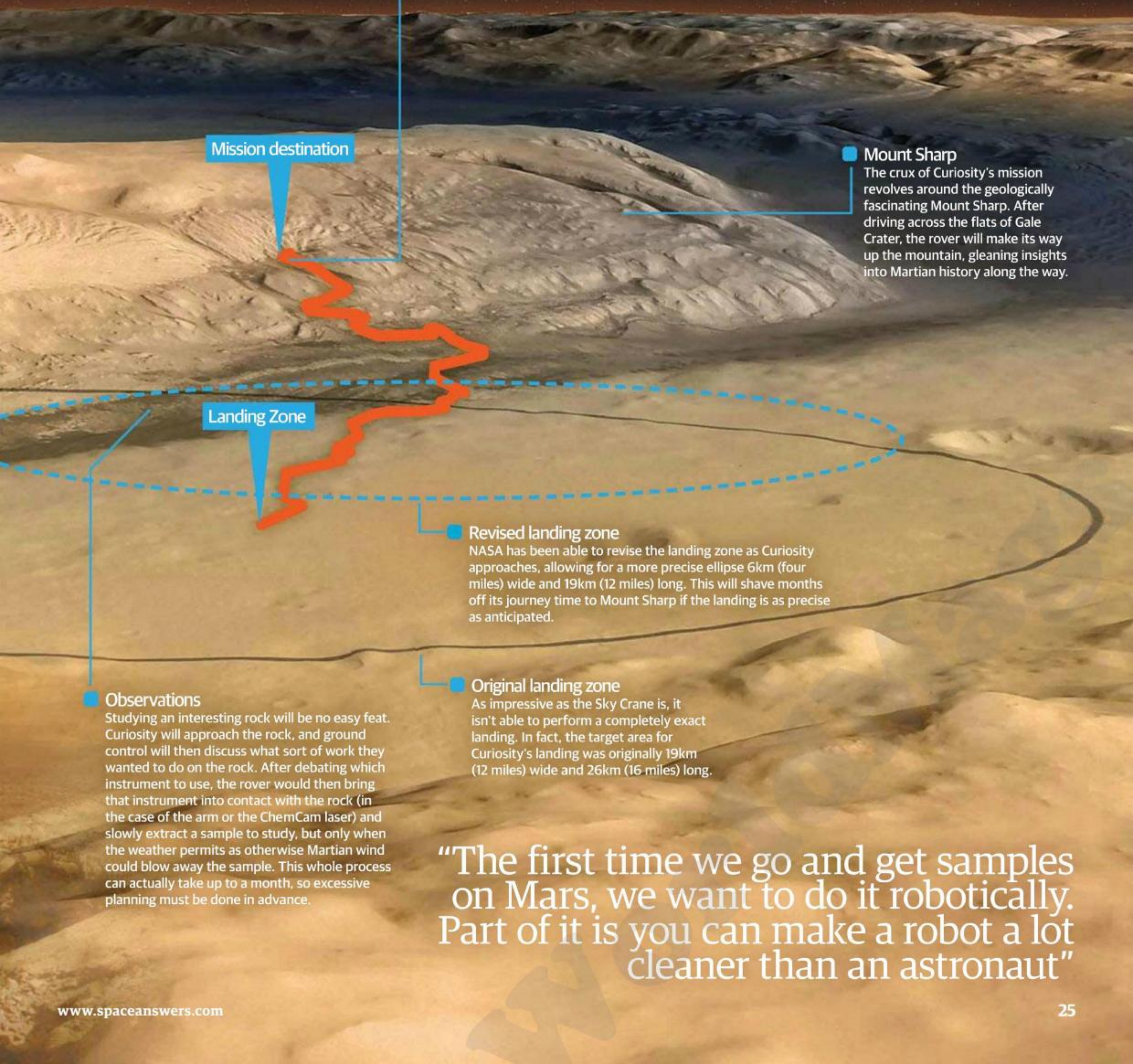
ChemCam
Curiosity's ChemCam laser will be able to vaporise rocks from a distance of seven metres (23 feet), allowing Curiosity to study the resultant gas for signs of organics.

Drill
The drill produces a fine powder that can be sampled by one of several instruments on board.



Mars is strewn with interesting rocks that could provide clues to its possibly wet past

Mission destination
Curiosity is scheduled to last for 668 Martian sols, which is equivalent to 686 Earth days. At this point it will have reached a significant distance up Mount Sharp, but the rover is actually expected to last for many years after this just as Opportunity has done.



Mount Sharp
The crux of Curiosity's mission revolves around the geologically fascinating Mount Sharp. After driving across the flats of Gale Crater, the rover will make its way up the mountain, gleaning insights into Martian history along the way.

Revised landing zone
NASA has been able to revise the landing zone as Curiosity approaches, allowing for a more precise ellipse 6km (four miles) wide and 19km (12 miles) long. This will shave months off its journey time to Mount Sharp if the landing is as precise as anticipated.

Original landing zone
As impressive as the Sky Crane is, it isn't able to perform a completely exact landing. In fact, the target area for Curiosity's landing was originally 19km (12 miles) wide and 26km (16 miles) long.

Observations
Studying an interesting rock will be no easy feat. Curiosity will approach the rock, and ground control will then discuss what sort of work they wanted to do on the rock. After debating which instrument to use, the rover would then bring that instrument into contact with the rock (in the case of the arm or the ChemCam laser) and slowly extract a sample to study, but only when the weather permits as otherwise Martian wind could blow away the sample. This whole process can actually take up to a month, so excessive planning must be done in advance.

> "The first time we go and get samples on Mars, we want to do it robotically. Part of it is you can make a robot a lot cleaner than an astronaut"

Manned missions to Mars

When and how will humans land on the Red Planet?

The holy grail for Mars exploration has for many decades been to ultimately land humans on the Red Planet. After the Apollo missions in the Sixties and Seventies it was widely believed that Mars was the logical next step, but funding cuts left NASA in Earth orbit despite having a rocket, namely the Saturn V, that would have been capable of taking humans to the surface of Mars.

Therefore, for four decades the thought of human exploration of Mars was left by the wayside as a variety of spacecraft and space stations were launched into Earth orbit and beyond. Now, however, Mars is back on the space-exploration agenda, and getting there could be achievable with some upcoming technologies.

For starters, NASA is building its own successor to the Saturn V, known as the Space Launch System (SLS). Capable of carrying over 100,000 kilograms (220,000 pounds) into orbit, the SLS will have the capability to take humans to Mars, and indeed that appears to be NASA's ultimate goal. It is thought that, in the 2020s, the SLS will launch astronauts in an Orion capsule on trips to the Moon and a near-Earth asteroid. The next step will be to either land on one of Mars's moons, Phobos or Deimos, or head straight for the Martian surface by the 2030s.

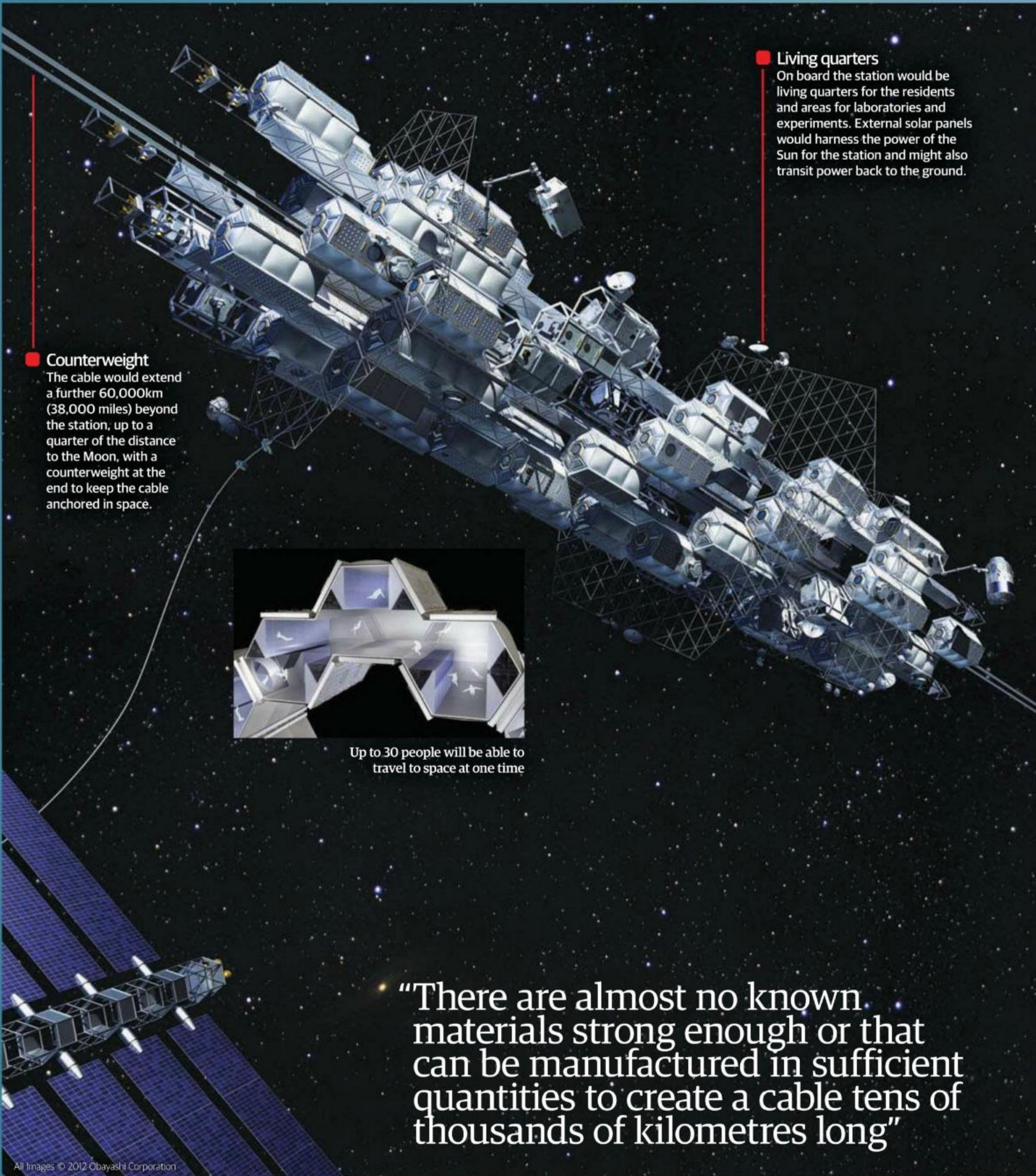
The other rocket that could get us there is SpaceX's Falcon Heavy rocket. Employing three of the boosters already used on the successful Falcon 9 rocket, the Falcon Heavy will be able to take over 50,000 kilograms (110,000 pounds) to orbit. By combining several such launches it could be possible to launch a mission to the Red Planet. In addition, SpaceX is working on its own variant of its successful Dragon capsule that docked with the International Space Station in May, known as the Red Dragon, that could be able to land on and take off from the surface of Mars.

As of now these are the two primary rockets that would be able to take humans to Mars. It's likely, though, that over the next decade more agencies such as China will announce heavy lift rockets capable of taking the giant spacecraft that will be needed to mount a six-month journey to Mars. However, while the possibility of humans stepping on another planet will be ever present, it will likely require international collaboration to have any chance of success. ●

Will humans ever be able to land on Mars? @spaceanswers #HumansOnMars

> "As of now these are the two primary rockets that would be able to take humans to Mars"

A huge amount of fuel and supplies is needed for a Mars expedition to survive the journey, the time on the surface and to have enough fuel to get back



Counterweight
The cable would extend a further 60,000km (38,000 miles) beyond the station, up to a quarter of the distance to the Moon, with a counterweight at the end to keep the cable anchored in space.

Living quarters
On board the station would be living quarters for the residents and areas for laboratories and experiments. External solar panels would harness the power of the Sun for the station and might also transit power back to the ground.

Up to 30 people will be able to travel to space at one time

> "There are almost no known materials strong enough or that can be manufactured in sufficient quantities to create a cable tens of thousands of kilometres long"

All Images © 2012 Obayashi Corporation

Space elevators

In the near future, could we be taking a lift into low Earth orbit?

Written by Jonathan O'Callaghan

Getting into space is no easy feat. At the moment we use huge tanks of propellant powered by giant explosions at their base, which are better known as rockets, but these are both dangerous and very expensive.

That's why various agencies have spent years looking for other ways to reach space. Last issue we looked at space planes, but this time we're focusing on a more ambitious way to have a constant connection to space.

The idea of a space elevator was first inspired by Russian scientist Konstantin Tsiolkovsky in 1895. In principle it sounds simple - have a tether extend from the surface of Earth to space and just travel up and down it. In practice, however, it's incredibly difficult to construct such a device. For starters, there are almost no known materials strong enough or that can be manufactured in sufficient quantities to create a cable tens of thousands of kilometres long. Second, the tether would need to be anchored both at a geostationary station and further out with a counterweight point to ensure it didn't break. Finally, you'll need some sort of elevator that can attach itself to the cable and travel into space.

Thankfully, there are solutions. One of the primary candidates for the cable's material is carbon nanotubes, which could possess the tensile strength needed for such a structure. Meanwhile, a counterweight beyond the orbit of the space station could be an asteroid or an additional space station. This would ensure the cable had a centre of gravity beyond the space station it was attached to, allowing it to remain anchored in space. Finally, by making the cable much wider at its centre point, cars could climb up it without destroying it. The counterweight would move to ensure the cars did not cause the cable to rotate too much and be destroyed. There are also several proposed methods to power the cars including solar power and wireless energy transfer.

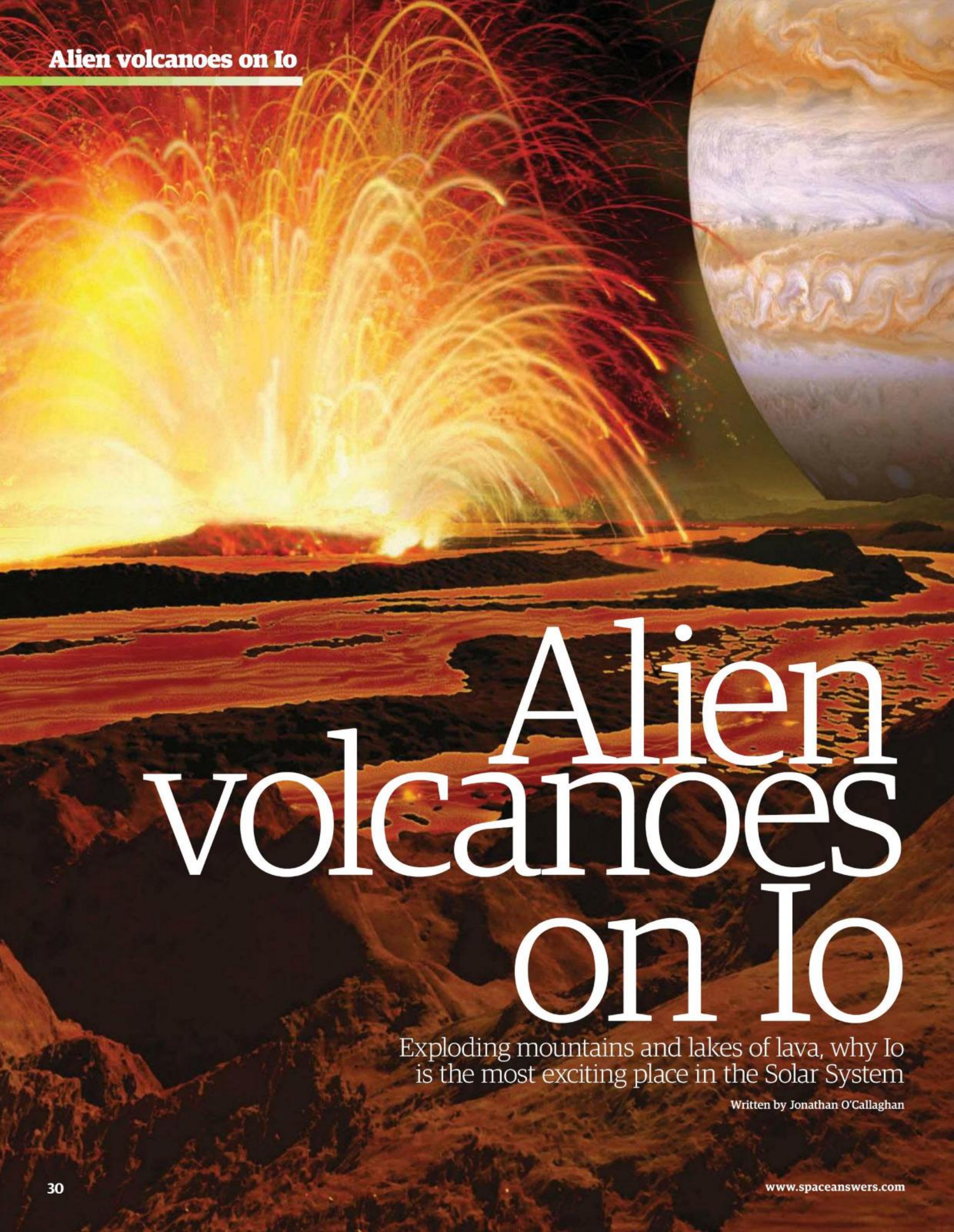
In 2012, Tokyo-based company Obayashi Corporation announced plans to build an operational space elevator by 2050. Although the project is merely in a concept phase, Obayashi Corp's proposal (pictured) isn't too out of this world. We won't be seeing one any time soon but, if all goes to plan, by 2050 we could all be taking regular trips to the stars.

Space elevator, space plane or a rocket - which would you choose? @spaceanswers #SpaceElevators

One end of the elevator's cable would be fixed to the Earth's surface near the equator

Constant access to space
Obayashi Corp's plan is to build a cable made of carbon nanotubes from the surface of Earth to a space station 36,000km (22,000 miles) high for constant and regular access to space.

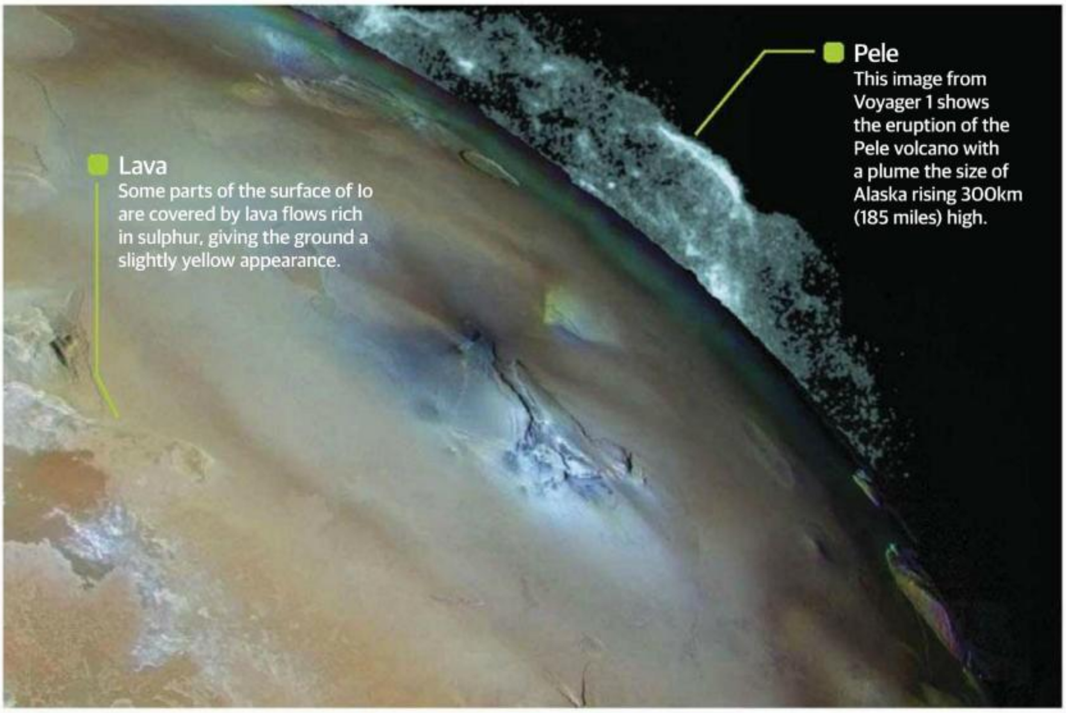
One-week journey
Travelling along the tether will be a passenger car that could hold up to 30 people and cargo. It will travel at about 200kph (124mph), making the journey last just over a week. One proposed method of propulsion for the car is magnetic linear motors.



Alien volcanoes on Io

Exploding mountains and lakes of lava, why Io is the most exciting place in the Solar System

Written by Jonathan O'Callaghan



Lava
Some parts of the surface of Io are covered by lava flows rich in sulphur, giving the ground a slightly yellow appearance.

Pele
This image from Voyager 1 shows the eruption of the Pele volcano with a plume the size of Alaska rising 300km (185 miles) high.

In 1979, NASA's two Voyager spacecraft flew by Io, the fourth largest moon in the Solar System and the innermost of Jupiter's four main Galilean moons, and returned some startling information. While moons in the Solar System were once thought to be lifeless hunks of space rock, both spacecraft had directly observed volcanic features on Io. Bearing more resemblance to a pepperoni pizza than a giant moon, it was apparent that Io was one of the most fascinating and significant objects in our Solar System.

Our own Moon is one that appears to have been active in the past but has quietened down to become almost entirely dormant, retaining little to none of the volcanic activity that once sculpted its surface. Indeed only a few planets, Earth included, have changeable environments at all, making the discovery of Io all the more exciting. Where once our Solar System was regarded as an ever-present museum of the past, moons such as this one have proven that it is still a lively and effervescent place. So what is it that makes Io so amazing?

To date, Io has more than 400 known active volcanoes, making it the most volcanically active object in the Solar System, even more so than Earth. Dozens of vents are strewn across its surface leaking gas into the atmosphere, while at its poles and even occasionally close to the moon's equator vast icy plains can be found. The remnants of Io's volcanic past and present are as clear as day, with large volcanic rings the size of California encircling either dormant or active volcanoes.

Volcanic plumes on Io can tower 300km (190 miles) in height and reach half the speed that would be needed to escape the gravity of the moon

While data from the Voyager probes, and later the Galileo spacecraft, has shown us volcanic plumes erupting from the surface of the moon, we are also able to discern some of Io's erupting monsters from observations on Earth. Some volcanoes have even been active for over two decades, meaning that the driving force below Io's surface is even more violent and ferocious than once thought.

The reason for Io's outbursts of activity is that it is being battered and bruised by Jupiter and its other moons. Io sits at a distance of 420,000 kilometres (260,000 miles) from Jupiter, which might sound quite far away but consider that our own Moon sits 385,000 kilometres (240,000 miles) away from us and that Jupiter is almost 318 times more massive than Earth, while Io is almost exactly the same size as our Moon. For this reason it's obvious that while the Earth exerts a small but noticeable force on the Moon, causing it to become gravitationally locked to our planet only a billion or so years ago, Jupiter is exerting a huge force on Io. This moon, which itself is gravitationally locked to

Jupiter, is being constantly pushed and pulled by the huge gas giant, which in turn is churning its insides. Add into this that the other three Galilean moons, of which Io is the second smallest but the closest to Jupiter, also exert a gravitational influence on the poor moon, and you might start feeling sorry for this troubled space rock. The influence of the other moons means that Io's orbit around Jupiter is eccentric, with a difference of 3,400 kilometres (2,100 miles) between its closest and furthest points. So, even though the same face always points towards Jupiter, Io experiences huge changes in gravitational force from this big bully of a planet.

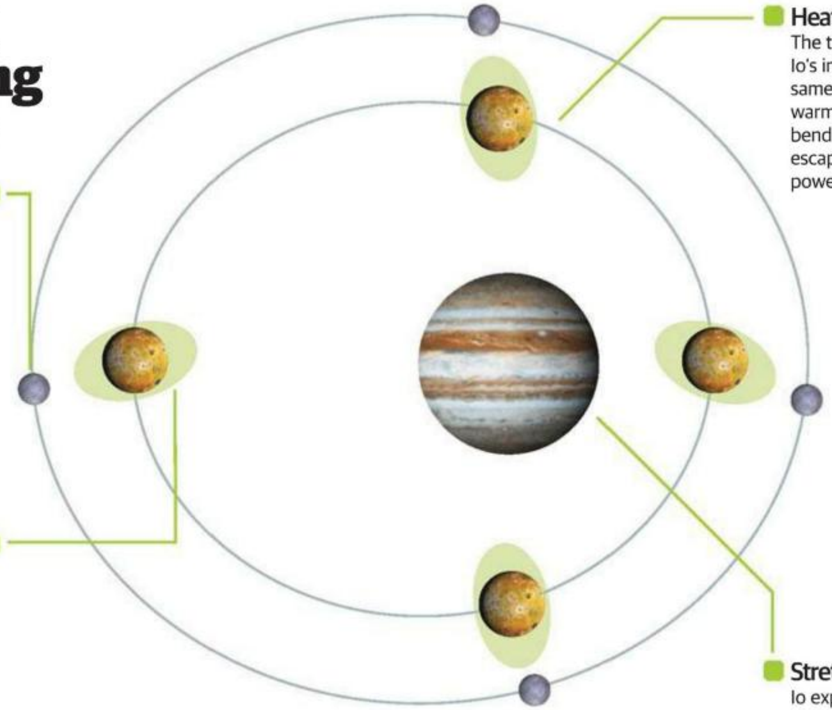
In fact, the force on Io is so intense that its solid surface acts in a similar manner to oceans on Earth. It bulges up and down by as much as 100 metres (330 feet) in places, compared to 18 metres (60 feet) for the highest tides on Earth. Bear in mind that Io's tides are made of solid rock and those on Earth are made of water, and you might realise just how tough a time this moon is having.

These tidal forces create a huge amount of heat in Io's interior, and therefore the majority of its subsurface crust is a liquid. This liquid is under intense pressure and looks for any escape route possible out onto Io's surface, be it in the form of a volcano, geyser or vent. This makes the surface a constantly changing place, with plumes of sulphur dioxide snow ejecting all over it. Any meteorites that hit the moon instantly see their impact craters filled with lakes of molten lava from the interior. The composition of this lava is still somewhat of a mystery but the two main theories suggest that it is either made from various compounds of molten sulphur or silicate rock. The former would account for the odd colouring of the moon, while the latter would better explain the hot temperatures under the surface where it may be too hot for sulphur to exist.

As more missions are sent to the Jupiter system we will learn more about this fascinating and mysterious moon. NASA's solar-powered spacecraft Juno, which launched in August 2011, will enter orbit around the largest planet in our Solar System in July 2016. This will be followed by the ESA's Jupiter Icy Moon Explorer, which is set to launch in 2022 and arrive at Jupiter in 2030. ■

Is Io of greater interest than other worlds like Titan and Europa? @spaceanswers #Io

Tidal flexing on Io



Europa
Io's orbit is not circular due to the gravity of neighbouring moons Europa and Ganymede.

Elliptical
Because of its elliptical orbit, Io is stretched and twisted over regular time periods.

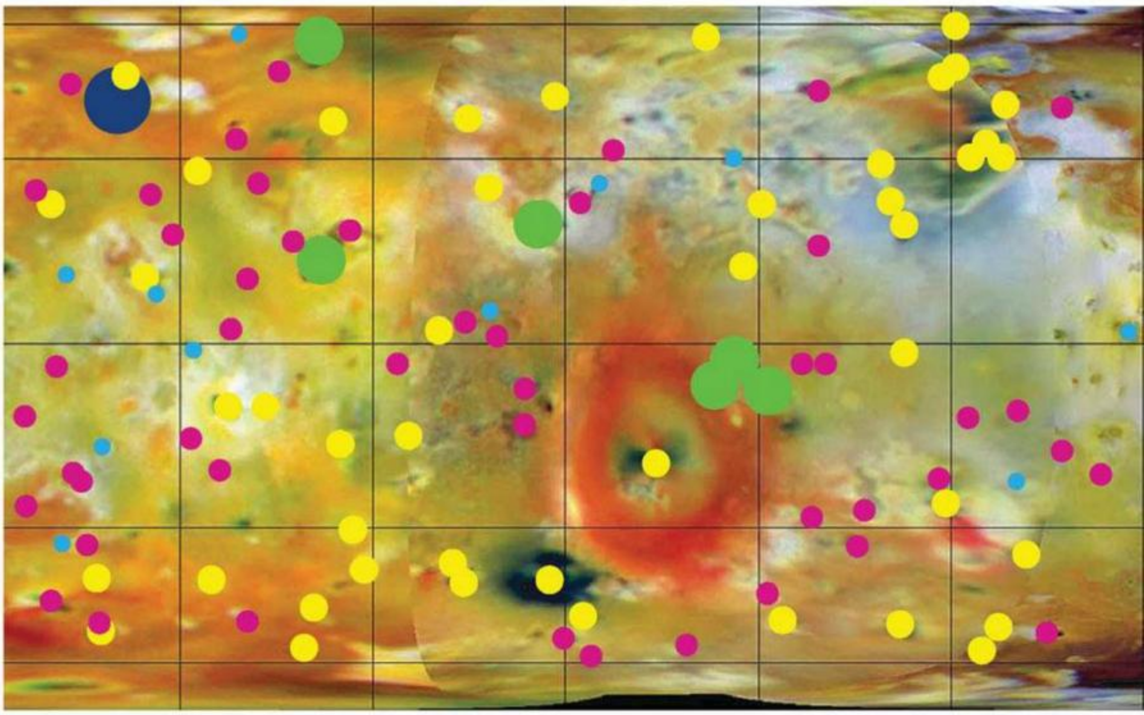
Heat
The tidal flexing heats Io's interior in the same way a paperclip warms when you bend it. The heat escapes through powerful eruptions.

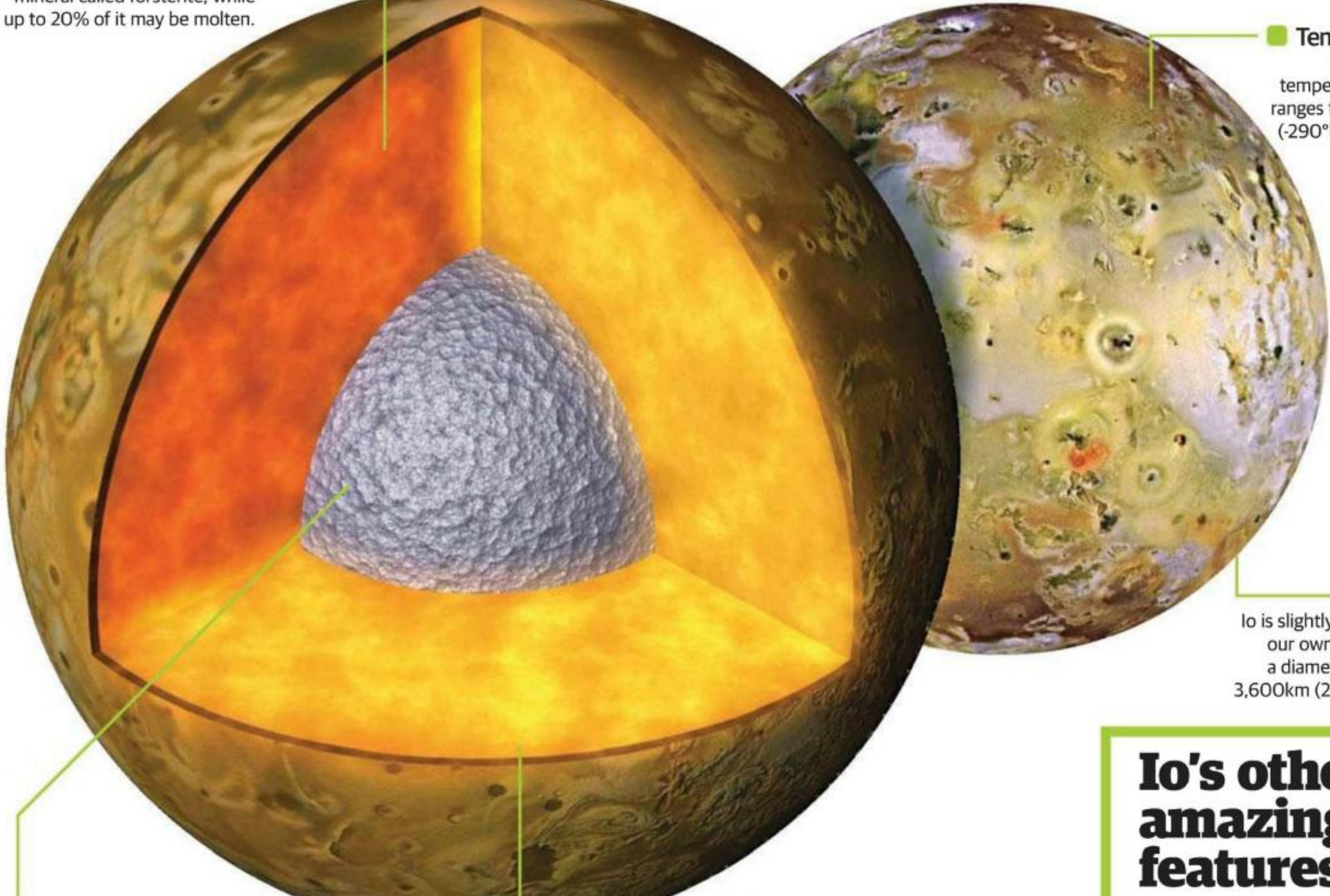
Stretched
Io experiences more tidal stretching from its host planet than our own Moon due to Jupiter's massive size.

Biggest volcanoes on Io

The strength of volcanoes on Io is measured using the gigawatt, a unit of power equal to a billion watts. For comparison, ten gigawatts is approximately equal to the power the Space Shuttle produced at lift-off

● >10,000 GW (gigawatts) ● 1,001-10,000 GW ● 101-1,000 GW ● 11-100 GW ● 1-10 GW





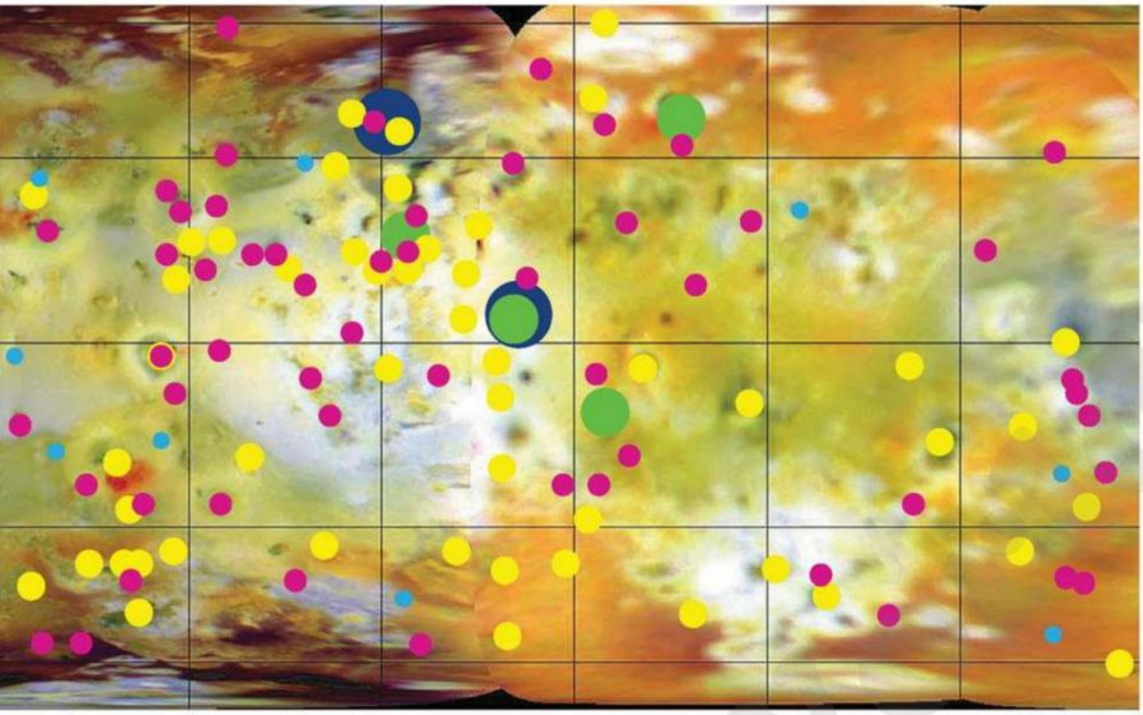
Mantle
The mantle of Io is thought to be made of a magnesium-rich mineral called forsterite, while up to 20% of it may be molten.

Temperature
The surface temperature on Io ranges from -180°C (-290°F) to -140°C (-220°F).

Size
Io is slightly larger than our own Moon with a diameter of about 3,600km (2,240 miles).

Core
Measurements made by the Voyager and Galileo spacecraft suggest that at Io's centre is an iron-rich core.

Lithosphere
The upper portion of the mantle, the lithosphere, is made of basalt and sulphur deposited from the various volcanoes on Io.



Io's other amazing features

Freezing cold

One of the most astounding things about Io is that, despite the number of active volcanoes on its surface, it has a maximum surface temperature of -140°C (-220°F). This is because Io's atmosphere is incredibly thin, with volcanic gases instantly freezing and condensing upon eruption rather than adding to the atmosphere like on Earth.

Lightning storms

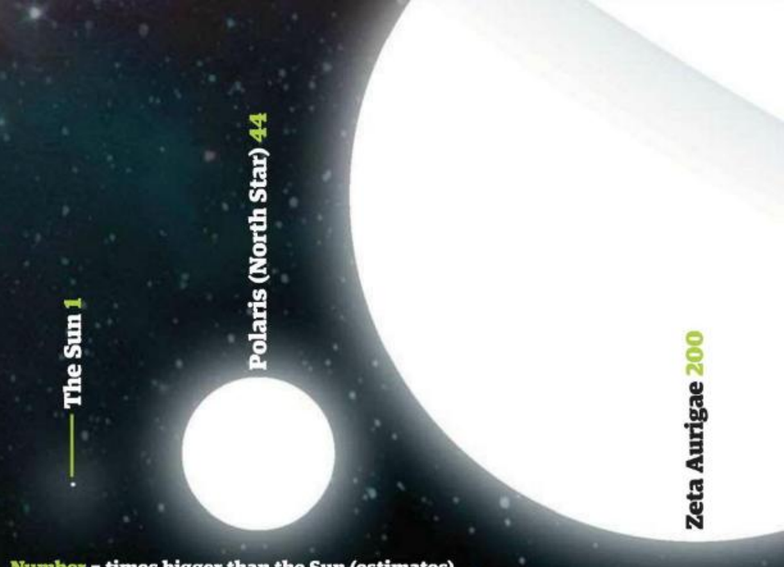
Io's orbit sees it cut across Jupiter's magnetic field lines, turning the moon into a giant electric generator. In fact, Io generates about 400,000 volts across itself, in turn creating 3 million amperes of current. This makes its way back along Jupiter's magnetic field lines and causes lightning storms in its upper atmosphere.

Magnetic field

The magnetic field of Jupiter also has another effect on Io. As it sweeps past the moon it actually strips off about 1,000kg (2,200lb) of material per second, which in turn becomes ionised and forms a ring-shaped cloud of radiation. The ions in this ring create auroras at the planet's poles, and also inflate Jupiter's magnetosphere to twice its expected size.

3 The largest known star is 1,900 times the size of the Sun

Our Sun is brighter than 85% of the stars in the Milky Way and is the fourth heaviest among its 50 nearest neighbours, but it is a minnow compared to some. The larger a star is, the faster it burns through its available fuel. The largest known star in the universe is VY Canis Majoris, which would engulf the orbit of Saturn if it replaced the Sun. This star will explode in a hypernova within the next 100,000 years, leaving a huge black hole behind.



Number = times bigger than the Sun (estimates)

4 You weigh different amounts in space

Although your mass (how much force it takes to accelerate you) is the same wherever you are in the universe, your *weight* (the downward force from gravity) depends on the size of the planet you are standing on. The more mass a planet has, the more it pulls you down onto the surface.

Mercury	29kg (63lb)
Mars	29kg (63lb)
Uranus	68kg (150lb)
Venus	70kg (154lb)
Earth	76kg (168lb)
Saturn	81kg (179lb)
Neptune	86kg (190lb)
Jupiter	180kg (397lb)

5 We sent an invitation to aliens

The Voyager 1 and 2 probes were launched in 1977 to study Jupiter and Saturn but their trajectory allowed them to continue past this point and head for the outer Solar System and beyond. On the off-chance that either of them encounters alien civilisations, the Voyager probes each carry a message from Earth.

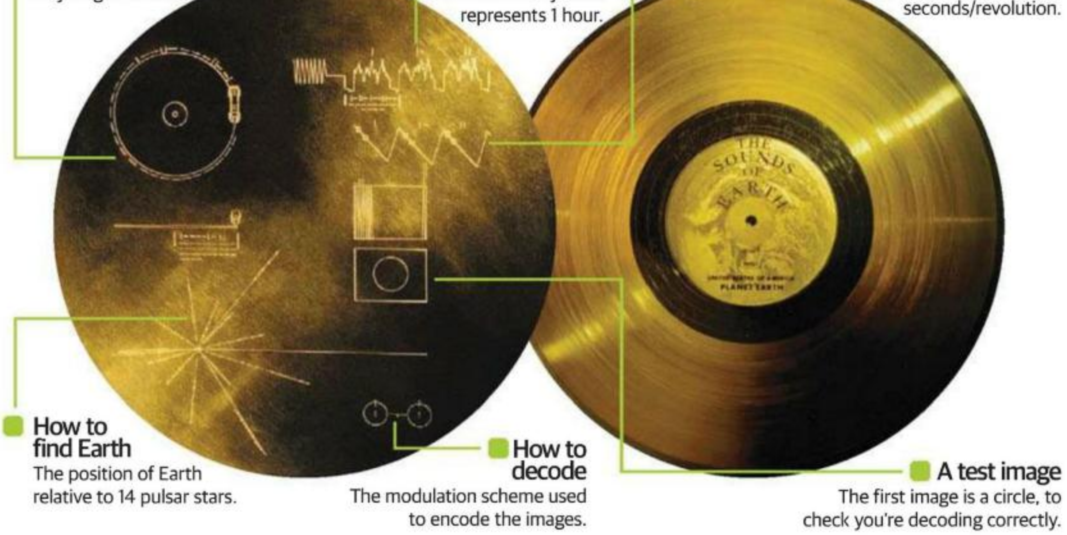
The Pioneer 10 and 11 probes launched in 1972 and 1973 respectively carried a simple gold-plated plaque with some diagrams, but the Voyagers had something much more sophisticated. An analogue record, similar to a vinyl LP but made of gold-plated aluminium, was used as a time capsule to tell aliens about life on Earth. As well as spoken greetings in 55 languages, the record includes sounds of music, surf, wind, bird calls and whale song.

More impressively, the record contains images as well. Before the invention of the Laserdisc and more than 20 years before DVD, the Voyager records used an analogue audio signal to encode 115 images at a resolution roughly equivalent to standard-definition TV pictures.

The images begin with diagrams that explain our system of numbers and gradually build to explain chemistry, human anatomy and biology and eventually our culture, science and engineering.

Although the system for recording images on the discs was state of the art for its time, an even bigger challenge was to devise a way of explaining to an alien civilisation how they should retrieve this information. Weight restrictions made it impractical to include complete playback equipment, so the Voyager probes only carried the record itself with a stylus cartridge positioned at the start of the first track. A series of diagrams on the protective cover were intended to explain how it worked using principles that would be applicable anywhere in the universe.

What would you say to aliens? @spaceanswers #FirstEncounter



A unit of time
Represents the spin of a hydrogen atom.

How long?
Side view of the record. Binary code represents 1 hour.

How fast?
The binary code round the edge represents 3.6 seconds/revolution.

How to find Earth
The position of Earth relative to 14 pulsar stars.

How to decode
The modulation scheme used to encode the images.

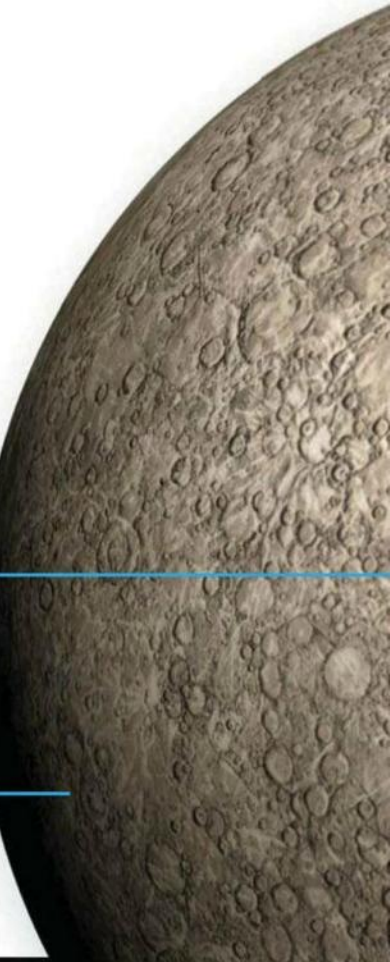
A test image
The first image is a circle, to check you're decoding correctly.

Mercury inside and out

Mercury has a huge core and a higher concentration of core iron than any other planet

Mercury contains about 30 per cent silicate materials and 70 per cent metals. Although it's so small, this make-up also means that it's incredibly dense at 5.427 grams per cubic centimetre, only a little bit less than the Earth's mean density. The Earth's density is due to gravitational compression, but Mercury has such a weak gravitational field in comparison to the Earth's. That's why scientists have decided that its density must be due to a large, iron-rich core. Mercury has a higher concentration of iron in its core than any other major planet in the Solar System. Some believe that this huge core is due to what was going on with the Sun while Mercury was forming. If Mercury formed before the energy output from the Sun stabilised, it may have had twice the mass that it does now. Then when the Sun contracted and stabilised, massive temperature fluctuations vaporised some of the planet's crust and mantle rock. Or a thinner mantle and crust may have always existed due to drag on the solar nebula (the Sun's cloud of dust and gas from which the planets formed) from the close proximity to the Sun itself. Our latest information from the Messenger spacecraft supports the latter theory, because it has found high levels of materials like potassium on the surface, which would have been vaporised at the extreme temperatures needed for the former theory. ●

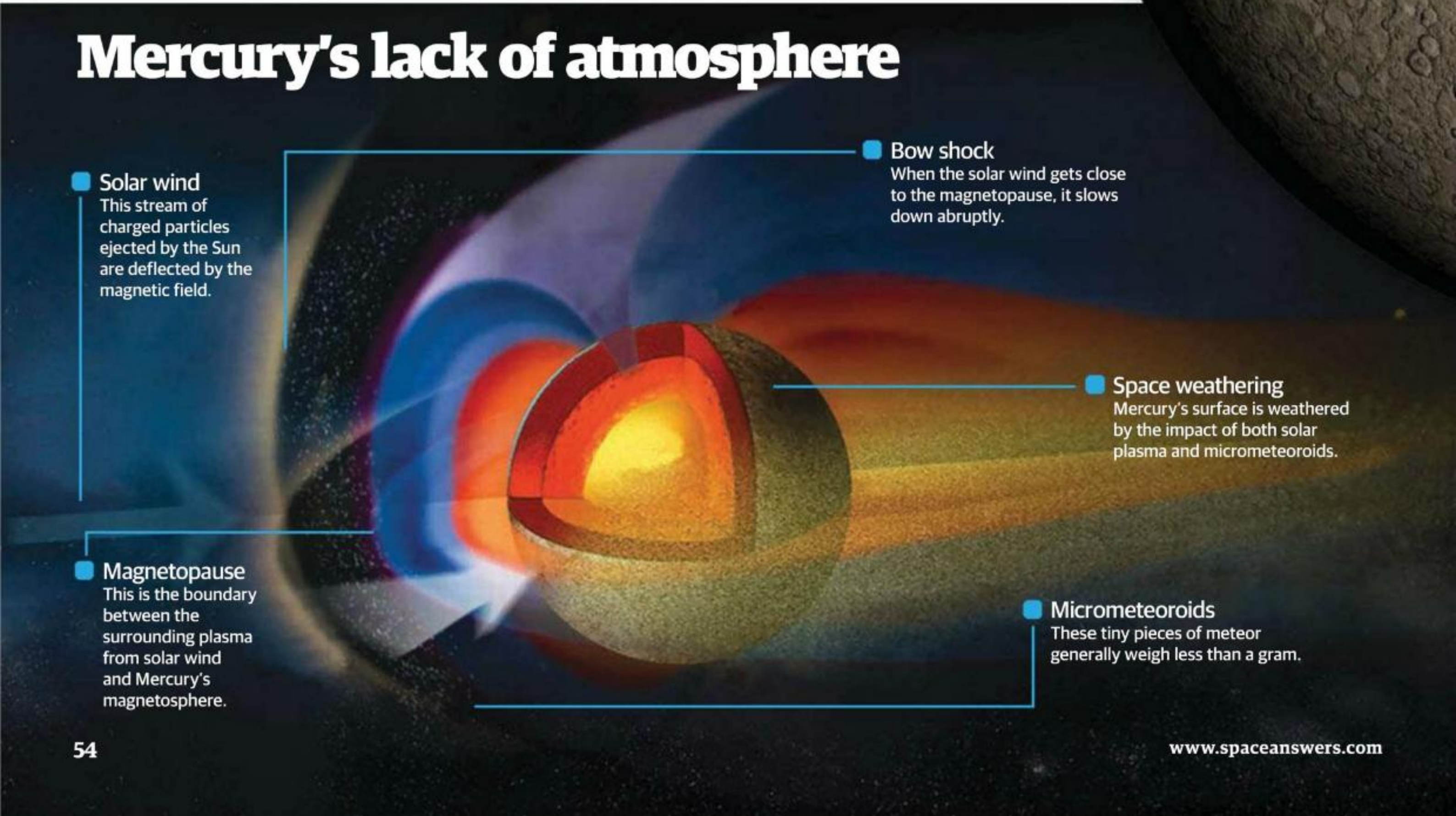
The structure of Mercury



Huge impact
Because the mantle is so thin compared to the core, some believe that there may have been a huge impact of some type that stripped away some of the original mantle.

Bombardment
The current crust may have formed after the bombardment, which was followed by volcanic activity that resulted in lava flows.

Mercury's lack of atmosphere



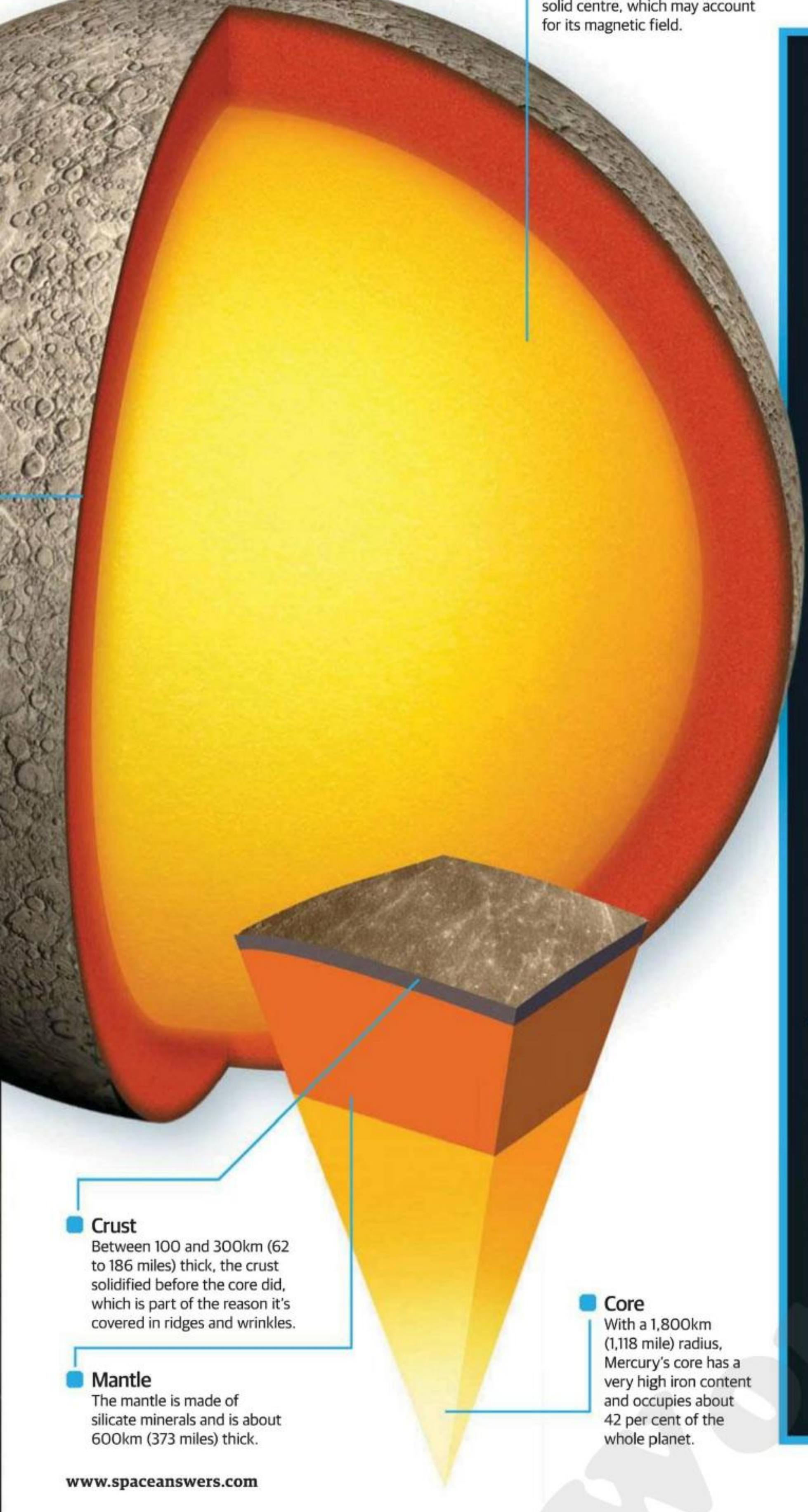
Solar wind
This stream of charged particles ejected by the Sun are deflected by the magnetic field.

Bow shock
When the solar wind gets close to the magnetopause, it slows down abruptly.

Space weathering
Mercury's surface is weathered by the impact of both solar plasma and micrometeoroids.

Magnetopause
This is the boundary between the surrounding plasma from solar wind and Mercury's magnetosphere.

Micrometeoroids
These tiny pieces of meteor generally weigh less than a gram.



Molten layers
The iron-rich core probably has molten layers surrounding a solid centre, which may account for its magnetic field.

Crust
Between 100 and 300km (62 to 186 miles) thick, the crust solidified before the core did, which is part of the reason it's covered in ridges and wrinkles.

Mantle
The mantle is made of silicate minerals and is about 600km (373 miles) thick.

Core
With a 1,800km (1,118 mile) radius, Mercury's core has a very high iron content and occupies about 42 per cent of the whole planet.

Mercury by numbers

Fantastic figures and surprising statistics about Mercury

176 DAYS

Mercury revolves in 59 Earth days but it takes 176 days for the Sun to return to the same point in the sky

2nd

Densest planet in the Solar System after Earth

427°

Mercury's maximum surface temperature

2.5x bigger

The Sun appears two and a half times larger in Mercury's sky than it does in Earth's

45%

Until the Messenger spacecraft began imaging Mercury in 2008, we'd only ever seen this much of the planet

0 moons

Mercury is one of the few planets which has no moons or satellites captive within its gravity well

7x stronger

The Sun's rays are seven times stronger on Mercury than they are on Earth

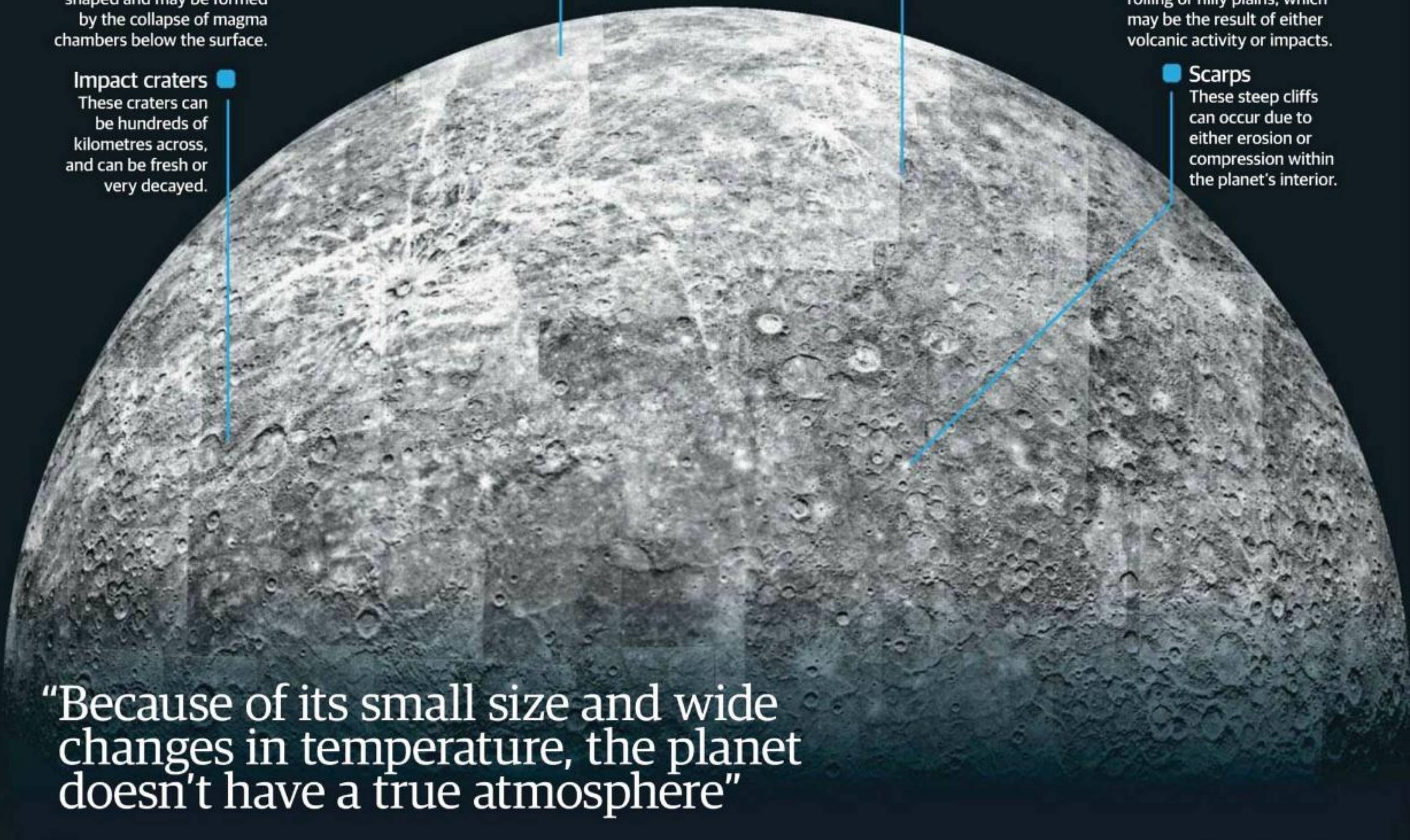
On the surface

Mercury is a planet of extreme variations in temperature, in its surface features and in its magnetic field

The surface of Mercury is not very well understood, but mapping by Mariner 10 and Messenger has revealed numerous craters and plains regions, crisscrossed with compression folds and escarpments. Not long after it formed, the planet was hit heavily and often in at least two waves by large asteroids and comets, which caused its extremely cratered surface. Couple this with periods of strong volcanic activity, which resulted in the smooth plains, and you have a very hilly surface.

Mercury can reach 427 degrees Celsius (800 degrees Fahrenheit), and there's a big difference between the temperature at the equator and the temperature at its poles. It has the most temperature variations of any planet in the Solar System, getting as low as -183 degrees Celsius (-297 degrees Fahrenheit). There may be deposits of minerals and ice within craters near the poles. The deepest craters are located there, and are the most likely candidates to hold ice because they always stay shadowed, never rising above -173 degrees Celsius (-279 degrees Fahrenheit).

Because of its small size and wide changes in temperature, Mercury doesn't have a true atmosphere. It has an unstable exosphere, a very loose, light layer of gases and other materials. Gases within it include helium, oxygen and hydrogen, some of which come from solar wind. Minerals such as calcium and potassium enter the exosphere when tiny meteors strike the surface and break up bits of rock. Mercury also has a magnetosphere, formed when the solar wind interacts with its magnetic field. Although that magnetic field is only about one per cent as strong as Earth's, it traps in some plasma from the solar wind, which adds to its surface weathering. The Messenger spacecraft discovered that Mercury's magnetosphere is somewhat unstable, causing bundles of magnetic fields to be pulled out into space and wrapped into tornado-like structures by the passing solar wind. Some of these tornadoes are as long as 800 kilometres (497 miles), or about a third of the planet's size. Before Mariner 10 flew by Mercury, it was thought not to have a magnetic field at all. The current theory is that it is caused by a dynamo, much like Earth's magnetic field, which means that the planet has an outer core of electrically conducive, rotating molten iron. Not all scientists agree that Mercury is capable of generating a dynamo, however.



Pit-floor craters
These craters are irregularly shaped and may be formed by the collapse of magma chambers below the surface.

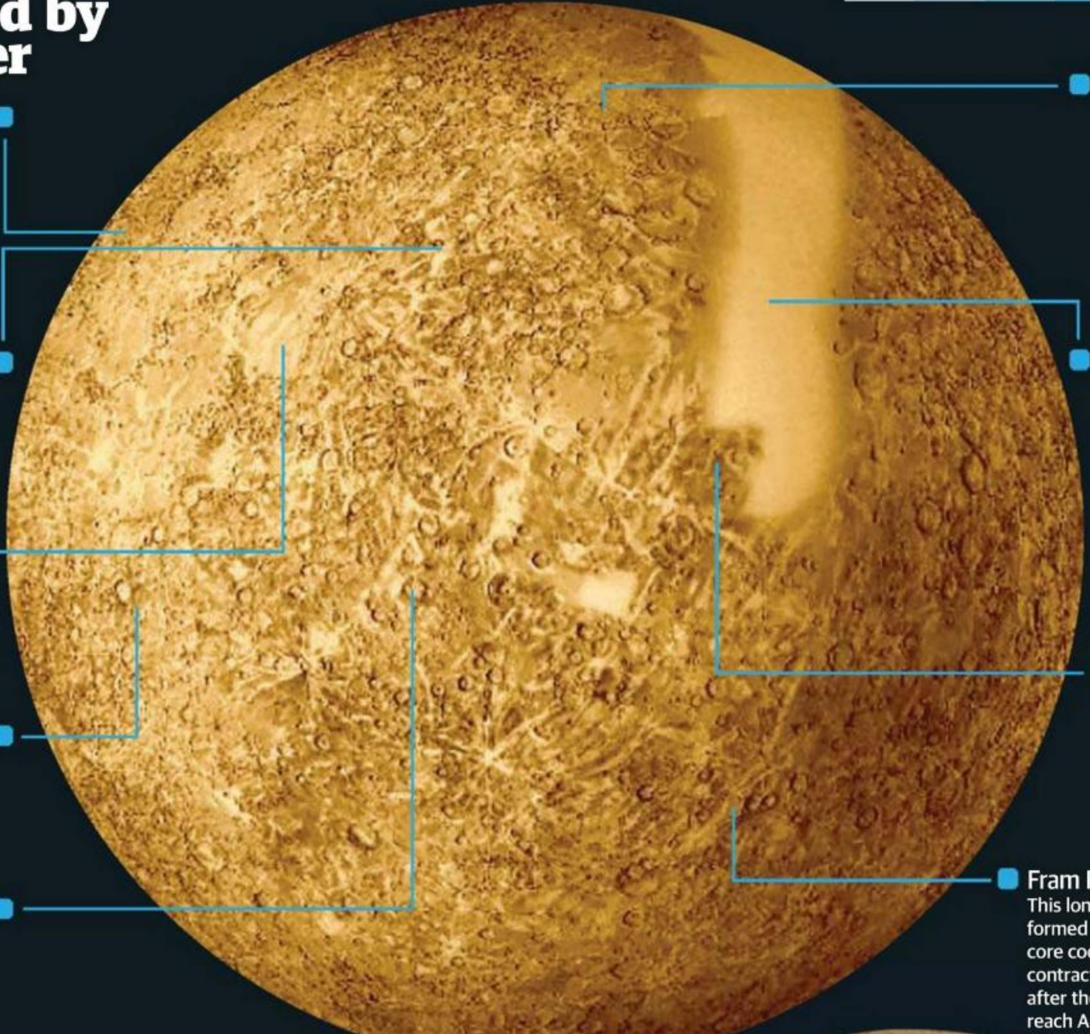
Impact craters
These craters can be hundreds of kilometres across, and can be fresh or very decayed.

Plains
There are both smooth and rolling or hilly plains, which may be the result of either volcanic activity or impacts.

Scarps
These steep cliffs can occur due to either erosion or compression within the planet's interior.

> "Because of its small size and wide changes in temperature, the planet doesn't have a true atmosphere"

Mercury mapped by Mariner



Caloris Basin
Not only is Caloris the largest impact crater on the planet at 1,550 km (960 miles) in diameter, it's one of the largest ones in the Solar System.

Sobkou Planitia
This plains region is home to several craters. Sobkou is the Egyptian messenger god.

Budh Planitia
The plains were named using alternative names for Mercury. Budh is its Hindu name.

Tolstoj Basin
The impact that caused this crater is thought to have occurred early in Mercury's history.

Bello
Bello is a crater named after a South American writer, and is about 129km (80 miles) in diameter.

Borealis Planitia
This basin has a smooth floor and may be similar to the basaltic basins on the Earth's Moon, also called lunar mares.

Blank area
Mariner 10 was only able to map about 45 per cent of Mercury's surface (the night-time side) and missed a few areas on that side as well.

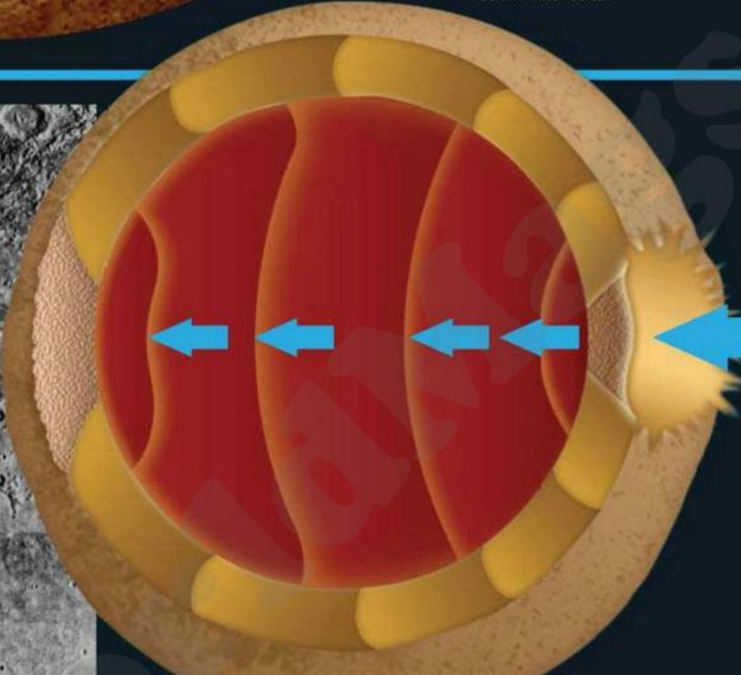
Vivaldi
This prominent crater is about 210km (130.5 miles) wide and has a double ring.

Fram Rupes
This long cliff was likely formed when Mercury's core cooled and contracted. It is named after the first ship to reach Antarctica.

The Caloris Basin

This diagram shows how the large impact craters on Mercury's surface - and particularly the Caloris Basin - have impacted the rest of the planet. At the antipode (a point on the other side of the planet exactly opposite of the basin), the ground is very uneven, grooved and hilly. It's called the Chaotic Terrain because it stands out so much among the otherwise smooth plains. The terrain may have formed due to seismic waves or material actually ejected from the antipode.

The image of Mercury's surface was taken at a distance of about 18,000km (11,100 miles)



Saturn's Monster storm

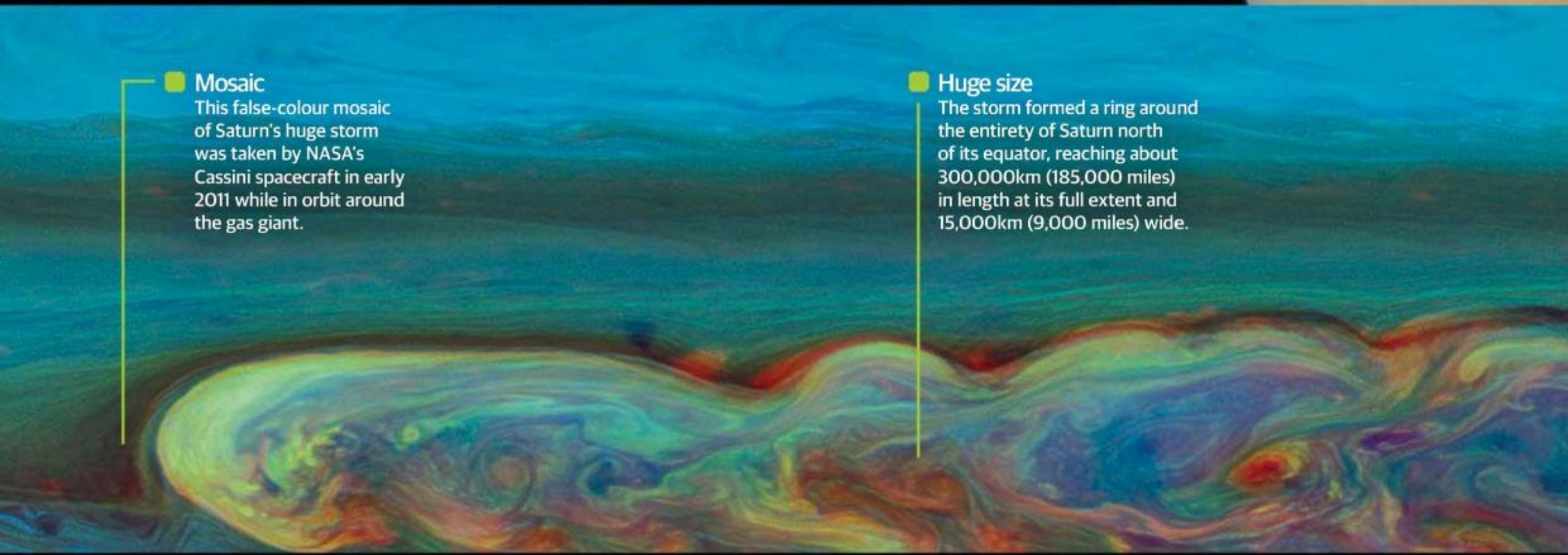
This mysterious storm was so big that it encircled the entire planet

Written by Jonathan O'Callaghan

A typical large storm on Earth might be anywhere up to a few hundred square kilometres in size. Imagine the amazement, therefore, when a storm on Saturn was found encircling the entire planet with a ridiculous size of 5 billion square kilometres (2 billion sqaure miles).

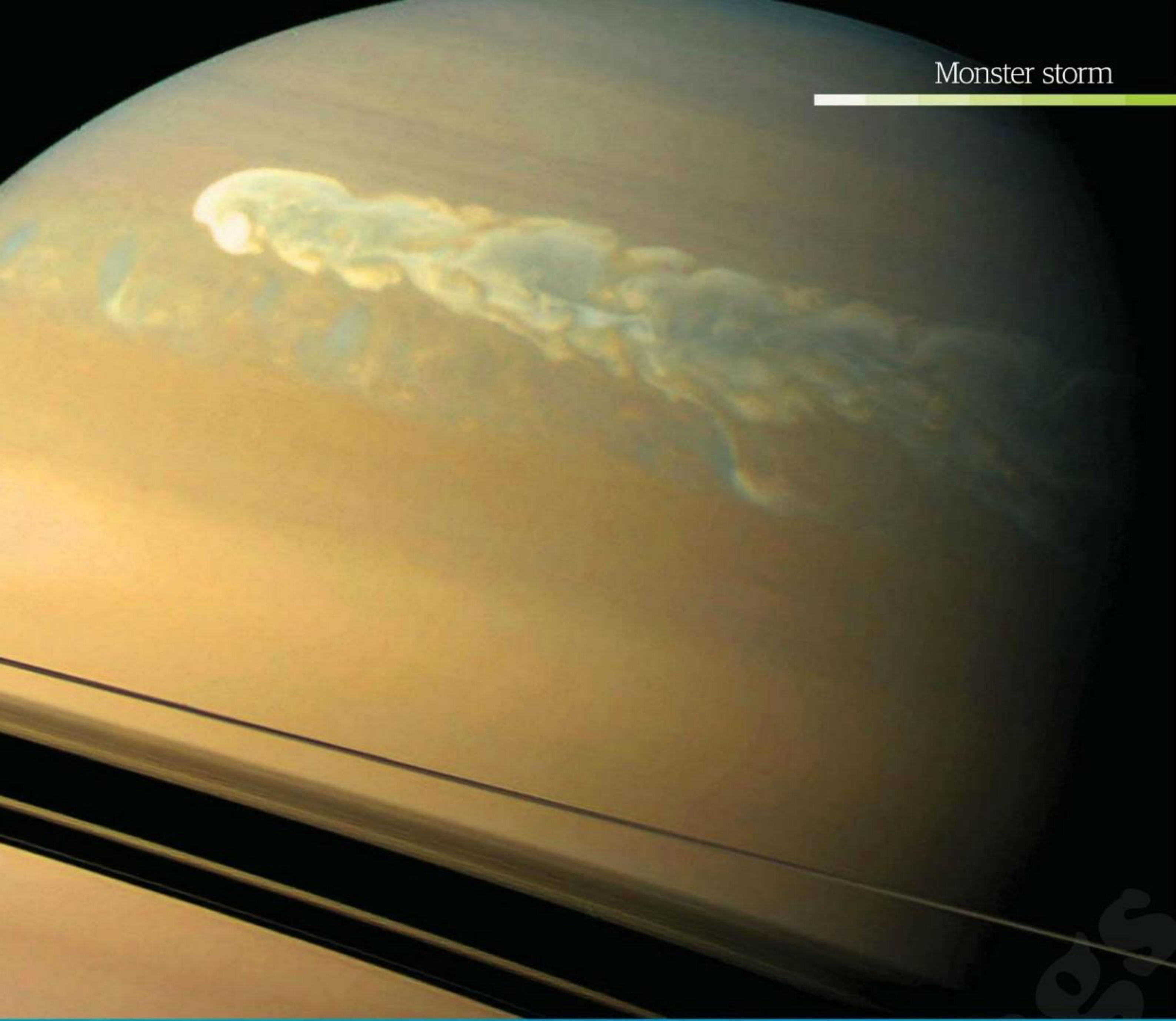
First spotted by amateur astronomers in late 2010, the Cassini spacecraft kept an eye on the storm until its demise in mid-2011, proving just how long storms in the outer Solar System can last for (such as the Great Red Spot on Jupiter, which has been raging for at least 400 years). This storm was the largest seen on Saturn since the Hubble Space Telescope imaged another large one two decades ago. It was active for 200 days, making it the longest planet-encircling storm ever seen on Saturn, beating the previous record holder from 1903 by 50 days. Inside the storm, which extended north to south about 15,000 kilometres (9,000 miles), clouds of methane gas swirl in the atmosphere of Saturn with winds in some parts reaching speeds of 1,800 kilometres per hour (1,100 miles per hour). While Cassini's high-resolution camera was snapping images, it also used its radio and plasma wave instrument to detect the storm's electrical activity and discovered that in places it was a raging convective thunderstorm.

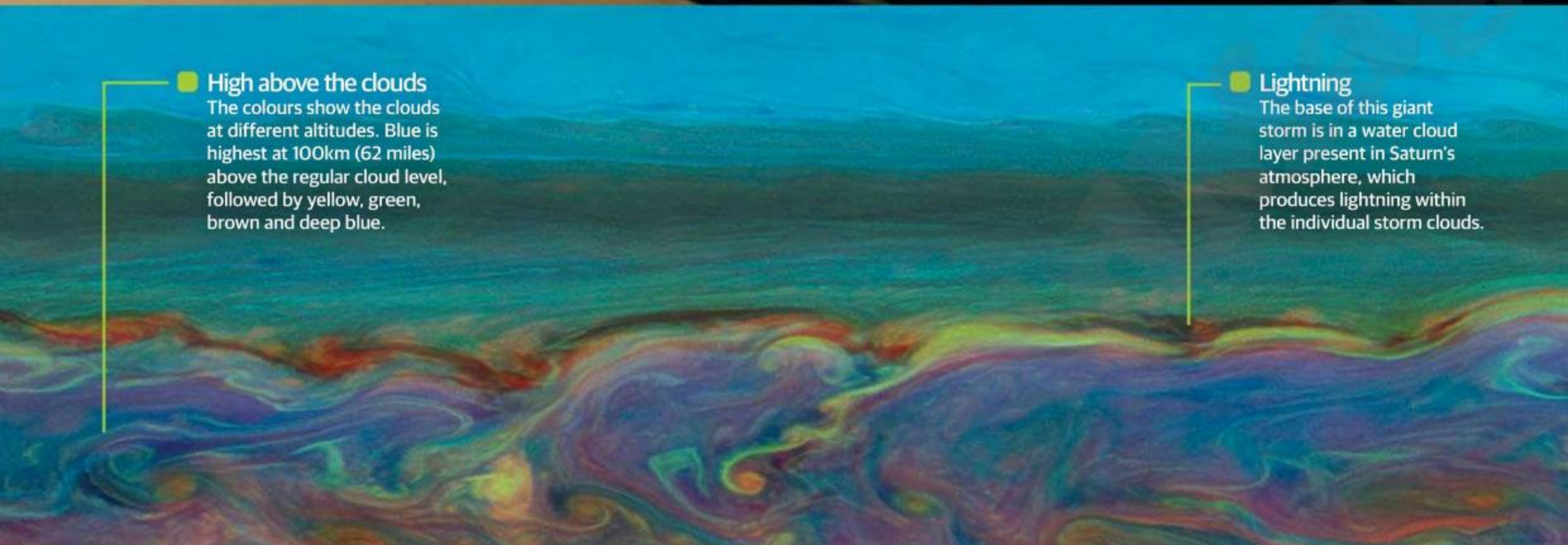
These storms, known as Great White Spots, seem to appear roughly every two or three decades, but their formation and origin is unknown. At times they appear to act more like volcanoes, with pressure building up until it is let out in one giant and long-lasting eruption. However, as there is nothing to resist the pressure until an eruption occurs, scientists are unsure how such pressure could build up and create these behemoths. What we do know is that this storm, which would reach about three-quarters the distance of the Earth to the Moon, is a cosmic force to be reckoned with.



Mosaic
This false-colour mosaic of Saturn's huge storm was taken by NASA's Cassini spacecraft in early 2011 while in orbit around the gas giant.

Huge size
The storm formed a ring around the entirety of Saturn north of its equator, reaching about 300,000km (185,000 miles) in length at its full extent and 15,000km (9,000 miles) wide.





High above the clouds
The colours show the clouds at different altitudes. Blue is highest at 100km (62 miles) above the regular cloud level, followed by yellow, green, brown and deep blue.

Lightning
The base of this giant storm is in a water cloud layer present in Saturn's atmosphere, which produces lightning within the individual storm clouds.

How might we get there?

Starship Daedalus, the fusion-powered interstellar spacecraft that could take us to another world

Project Daedalus was a feasibility study carried out by the British Interplanetary Society, to demonstrate that present and near-future technological developments could be used to build an unmanned interstellar spaceship.

From 1973 to 1978, a team of 13 designers carried out the study, which determined that Daedalus would take four years to reach 38,600km/sec (24,000 miles/sec). At this rate, it could reach the 5.9 light year distance to Barnard's Star in 50 years, where it would gather data during a two-day flyby through Barnard's solar system.

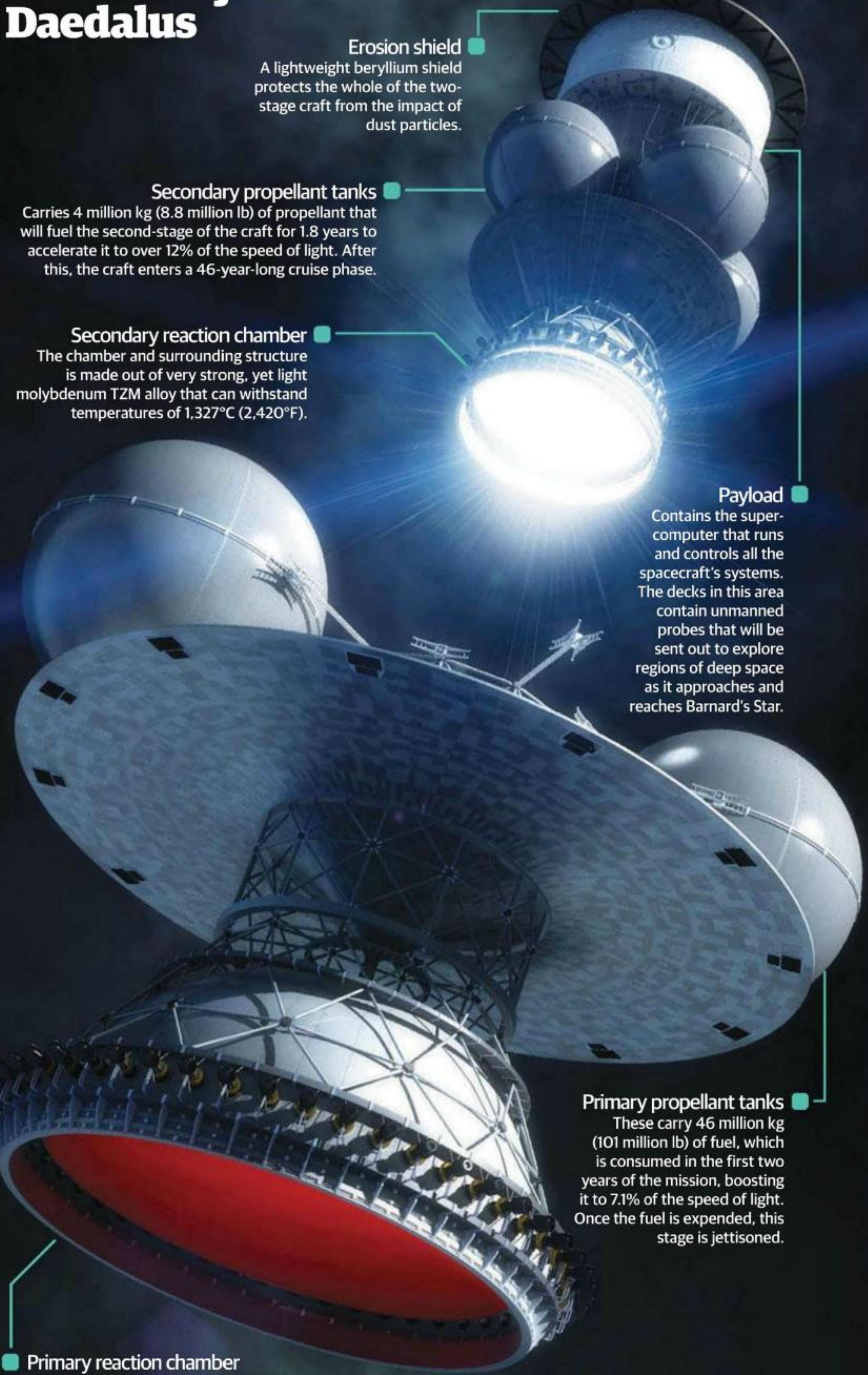
The vast scale of this project is underlined by the fact that the helium-3 fuel to power the craft has to be gathered in the atmosphere of Jupiter. This project itself would take 20 years for robot factories, held afloat by huge balloons, to mine and process the fuel into coin-sized pellets.

The two-stage craft, has a staggering total weight of 54 million kg (119 million lb), almost 20 times heavier than the Saturn V rocket. It would be constructed in Earth orbit or near Jupiter and propelled by a fusion pulse propulsion engine.

To propel it, 250 deuterium and helium-3 fuel pellets per second are injected into the engine's reaction chamber and detonated by high-energy electron beams. The plasma produced is channelled by magnetic fields to accelerate the ship to over 12 per cent the speed of light.

Whatever the target of its mission, Daedalus would be a huge undertaking that would absorb the material and financial resources of several nations over a long period of time. ***Should more money be invested in exploring interstellar travel @spaceanswers #newearths***

Inside Project Daedalus



Erosion shield
A lightweight beryllium shield protects the whole of the two-stage craft from the impact of dust particles.

Secondary propellant tanks
Carries 4 million kg (8.8 million lb) of propellant that will fuel the second-stage of the craft for 1.8 years to accelerate it to over 12% of the speed of light. After this, the craft enters a 46-year-long cruise phase.

Secondary reaction chamber
The chamber and surrounding structure is made out of very strong, yet light molybdenum TZM alloy that can withstand temperatures of 1,327°C (2,420°F).

Payload
Contains the super-computer that runs and controls all the spacecraft's systems. The decks in this area contain unmanned probes that will be sent out to explore regions of deep space as it approaches and reaches Barnard's Star.

Primary propellant tanks
These carry 46 million kg (101 million lb) of fuel, which is consumed in the first two years of the mission, boosting it to 7.1% of the speed of light. Once the fuel is expended, this stage is jettisoned.

Primary reaction chamber
This chamber works using the same principle as the second-stage reaction chamber, although it is much bigger. Four magnetic field coils guide the plasma downwards to propel the craft forwards.